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New England Division
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CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

BEHAVIOR OF BEACH FILL AND
BORROW AREA AT PROSPECT BEACH
WEST HAVEN, CONNECTICUT

TECHNICAL MEMORANDUM NO. 127



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FOREWORD

This report presents the results of a study of the movement of beach material made in connection with a beach fill and groin construction project at Prospect Beach, Connecticut. The project was undertaken by the State of Connecticut with Federal assistance in accordance with plans developed by the Corps of Engineers.

In addition to its mission of studying erosion problems at specific localities, the Beach Erosion Board has the mission of making general investigations to determine suitable methods, in general, for the protection, restoration and development of beaches. The study reported herein was made under the part of the Board's general investigations program concerned with the results obtained by work completed under shore protection projects and development of criteria for the design of beach fill projects.

The most economical method of protecting long reaches of shore is frequently found to be placement of suitable sand to provide a protective beach, and maintaining the required beach dimensions by periodically replacing the material eroded from the beach zone. This method of protection is being used at a number of places along the shore line of the United States. In the case of Prospect Beach groins were included in the plan to help stabilize the beach and reduce replenishment requirements. The beach fill project for Prospect Beach is of particular interest as the beach fill material was taken from the nearby offshore zone. Although fill material has been similarly obtained for several other projects, at the present time there are no established criteria for the optimum distance of the offshore borrow area from the beach zone.

This report was prepared by William H. Vesper, Engineering Division, Beach Erosion Board, under the supervision of Jay V. Hall, Jr., Chief of the Division. Much of the field data used herein were furnished by the U. S. Army Engineer Division, New England. At the time this report was prepared the Technical Staff of the Board was under the supervision of Major General Keith R. Barney, President of the Board, and R. O. Eaton was Chief Technical Advisor. The report was edited for publication by A. C. Rayner, Chief of the Project Development Division.

Views and conclusions expressed in the report are not necessarily those of the Beach Erosion Board.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945.

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BEHAVIOR OF BEACH FILL AND BORROW AREA
AT PROSPECT BEACH, WEST HAVEN, CONNECTICUT

by

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Introduction

Immediately prior to 1957, the beach at Prospect Beach, Connecticut consisted of coarse material, generally shingle, cobbles and boulders, with ledge rock outcrops in the vicinity of and west of Oyster River. The width of beach above the mean high tide line ranged from 0 to 40 feet in front of walls, revetments, and eroding bluffs. Beach slopes, between high and low waters, varied from 1 on 9 to 1 on 28. A sanitary sewer closely bordered the shore, and due to beach recession it had been necessary to construct seawalls andrevet the shore to protect the sewer from wave attack. The town of West Haven had spent about \$70,000 over a 10-year period constructing and maintaining these protective structures.

In 1951, the U. S. Army Corps of Engineers, in cooperation with the State of Connecticut, completed a cooperative beach erosion study of the Connecticut shore from New Haven Harbor to the Housatonic River.* The purpose of that study was to determine the most suitable methods of stabilizing and improving the shoreline in this area. Prospect Beach is one segment of this shore. The recommended plan of improvement for Prospect Beach involved widening the beach to a 100-foot width by direct placement of sand, and construction of eight impermeable groins. The plan provided for additional widening of the beach at the southerly end of the fill, as this sector of the beach fill was expected to be eroded at a more rapid rate, and to provide advance nourishment to the widened beach. Groins were included in the plan, as the study showed that losses from the proposed beach fill would be excessive without these structures. Behavior of beach fill placed in 1948 on the adjacent shore north of Bradley Point indicated that the only appreciable loss of fill occurred between the high and low water lines. Thus it was believed that groins only about 330 feet in length would be required at Prospect Beach. The short groins would permit the passage of some sand from the south end of the fill area to nourish the beach to the north, and thereby permit more economical maintenance of the entire area by periodically placing sand at the south end.

The recommended beach was to have a berm elevation 9.5 feet above mean low water and a minimum width of 100 feet at mean high water (+6.4 feet MLW), with added width of about 50 feet along the more exposed south end of the beach adjacent to Oyster River Point. The estimated quantity of sand required was 380,000 cubic yards for the initial fill, and an average of 8,400 cubic yards annually for nourishment.

* Area 3 - New Haven Harbor to Housatonic River, Conn., Beach Erosion Control Study. Published as House Doc. No. 203/83/1

Summary of Physical Data*

Prospect Beach is a suburban and resort development located in the town of West Haven (see Figure 1). It comprises about 6,470 feet of the Connecticut shore along Long Island Sound, between Oyster River Point and Bradley Point. This segment of shore extends generally in a northeasterly-southwesterly direction and is exposed to wave attack from the south and southwest. It is protected from easterly waves by breakwaters at the entrance to New Haven Harbor.

Littoral drift probably moves only toward the northeast on the Prospect Beach shore. Tides in the area are semidiurnal with mean and spring ranges of 6.4 and 7.5 feet respectively. No continuous record of storm tides is available for the area. The highest tide on record occurred during the hurricane of September 21, 1938, when it reached an elevation of 13 feet above mean low water.

Project Construction

The State of Connecticut initiated construction of this project in February 1957. The beach was widened between South and Ivy Streets (Ranges D and 8+00, shown on Figure 1). This is a shoreline distance of about 6,000 feet. A total of 443,000 cubic yards (measured in place on the beach) of sand fill was placed by hydraulic pipeline dredge; the cost of about \$292,500 included costs of storm drain inclosures. The borrow area about 450 feet wide and 2,000 feet long, located approximately 1,000 feet offshore between ranges 16 and 40, was dredged to an average depth of 14.5 feet below mean low water. Samples of the fill material had median diameters ranging from 0.22 to 0.89 millimeter. The eight impermeable groins were constructed after the fill was placed at locations shown on Figure 1. They were completed in May 1957 at a cost of about \$56,000. An average of 860 tons of stone was required for each groin, and the average length of the groins is 310 feet. The seaward ends of the groins terminated at about mean low water on the filled beach. A typical groin profile and section are shown on Figure 2.

Survey Data

Profiles of the shore and offshore bottom were obtained at intervals of approximately 200 feet (34 profiles) along the entire stretch of shore in January 1956 (before placement of beach fill) and were repeated in March 1957 (immediately after filling). Condition surveys were made in June 1958, June 1959, and June 1960. In the resurvey of June 1960, twenty profiles were taken. The 1960 profiles extended across the borrow area and were taken on alternate ranges of the previous surveys except that four consecutive profiles were taken at the east end of the borrow area and three at the west end. Soundings across the borrow area before and after dredging respectively were obtained at intervals of approximately 50 feet in January and February 1957. Range locations are shown on Figure 1, plots of the profile data on

* Summarized from op. cit.

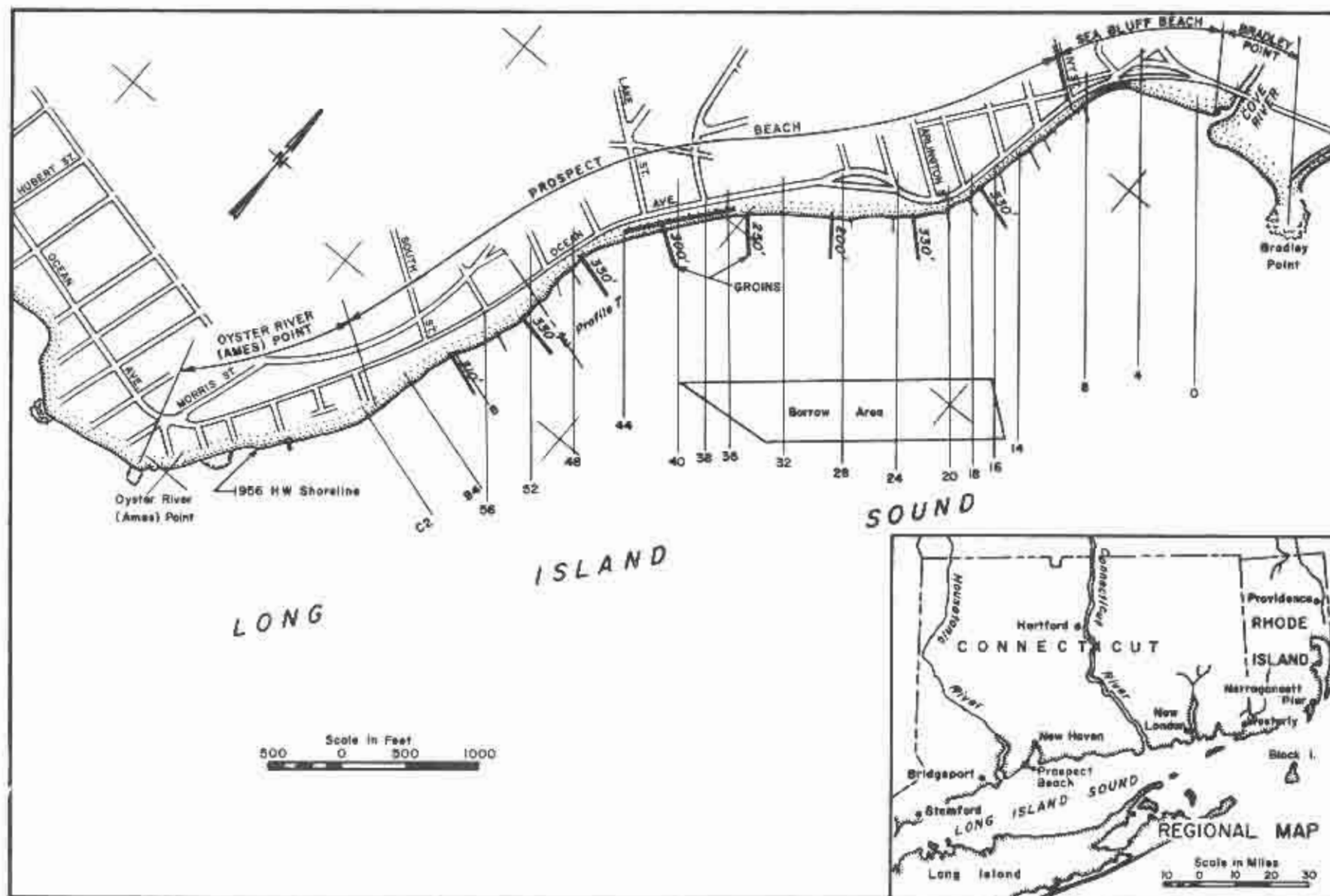


FIGURE 1. PROSPECT BEACH-WEST HAVEN, CONNECTICUT

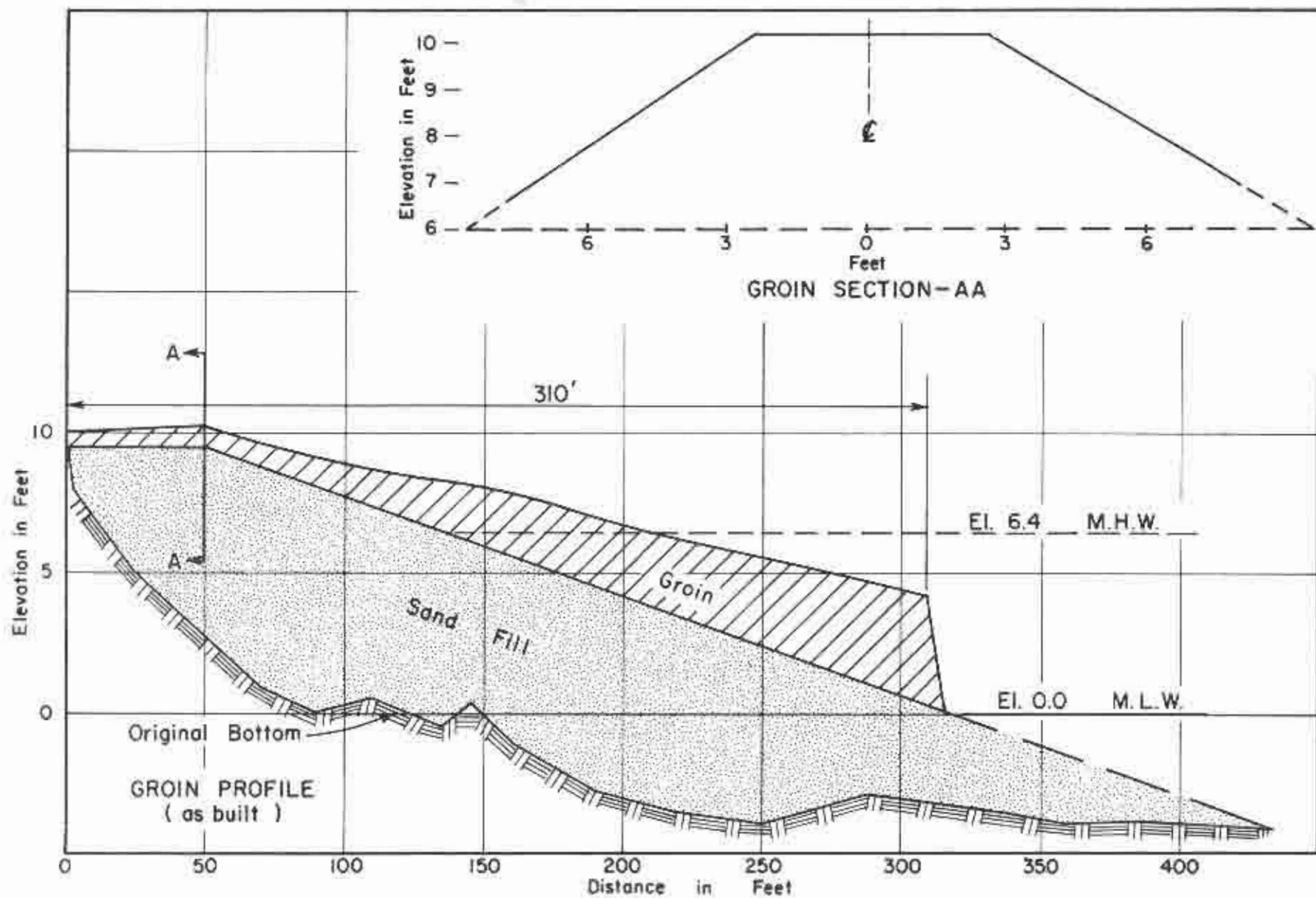


FIGURE 2. TYPICAL GROIN AT PROSPECT BEACH , CONNECTICUT

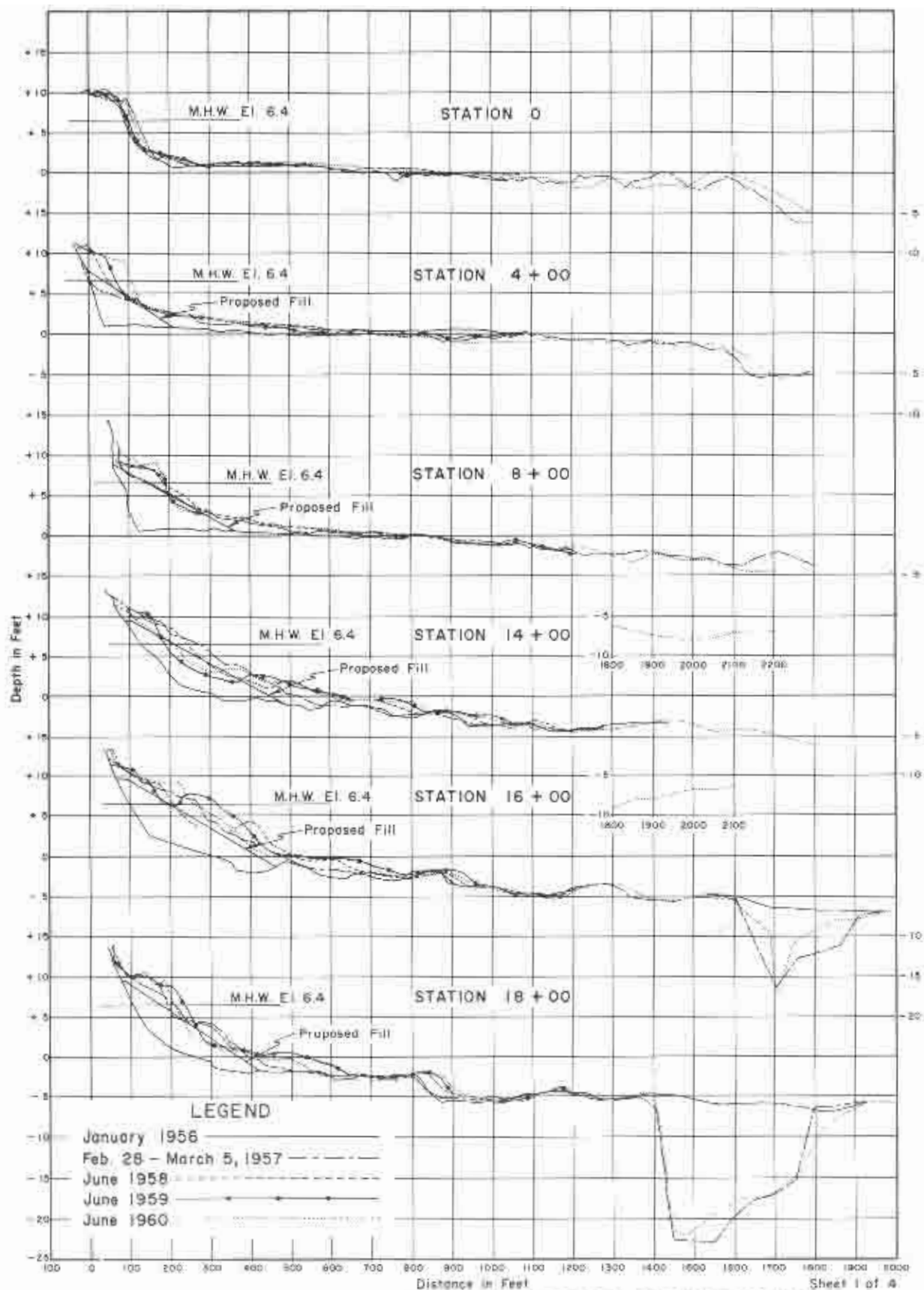


FIGURE 3. PROFILES - PROSPECT BEACH, CONNECTICUT

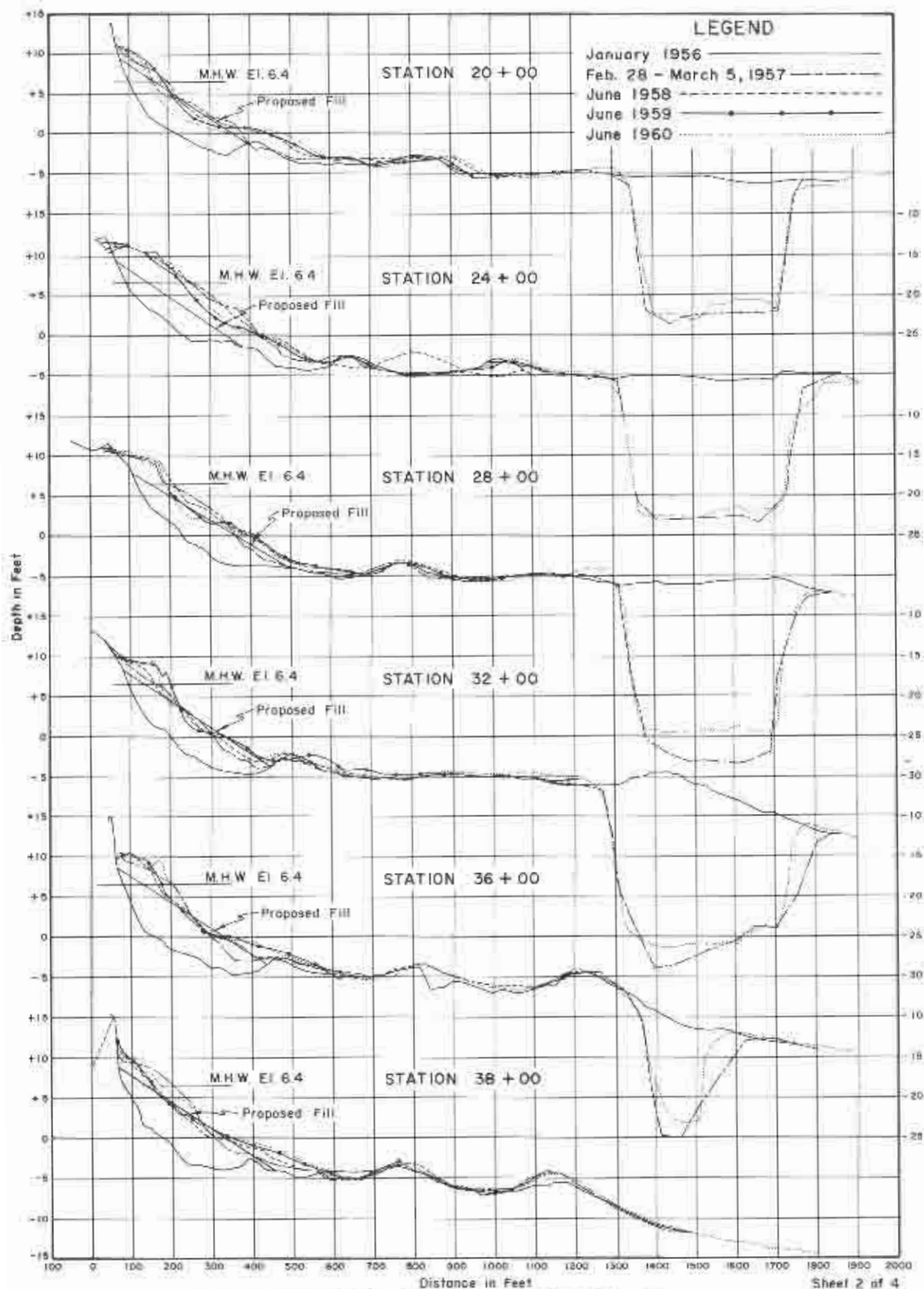


FIGURE 3. PROFILES - PROSPECT BEACH, CONNECTICUT

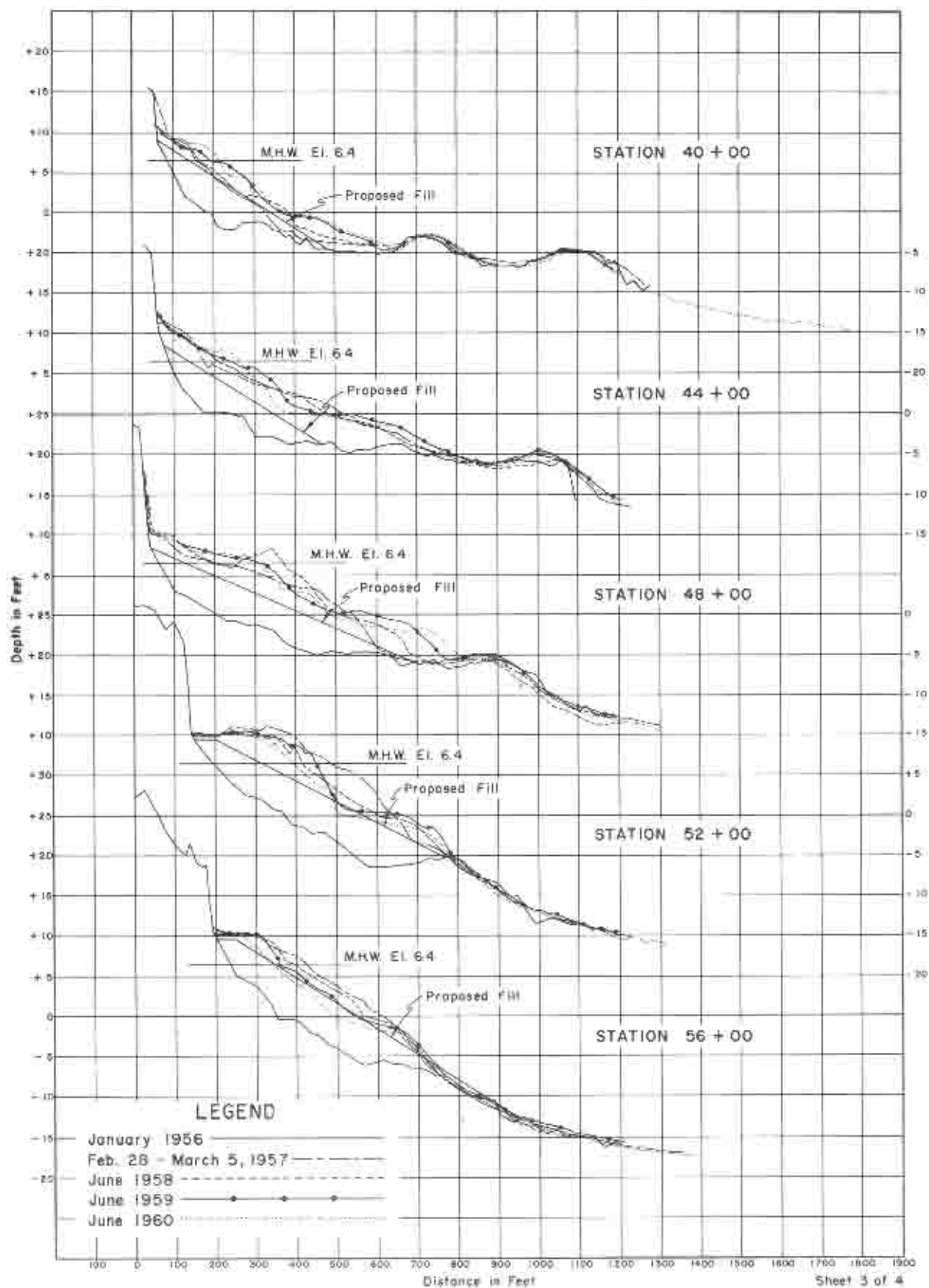


FIGURE 3. PROFILES - PROSPECT BEACH, CONNECTICUT

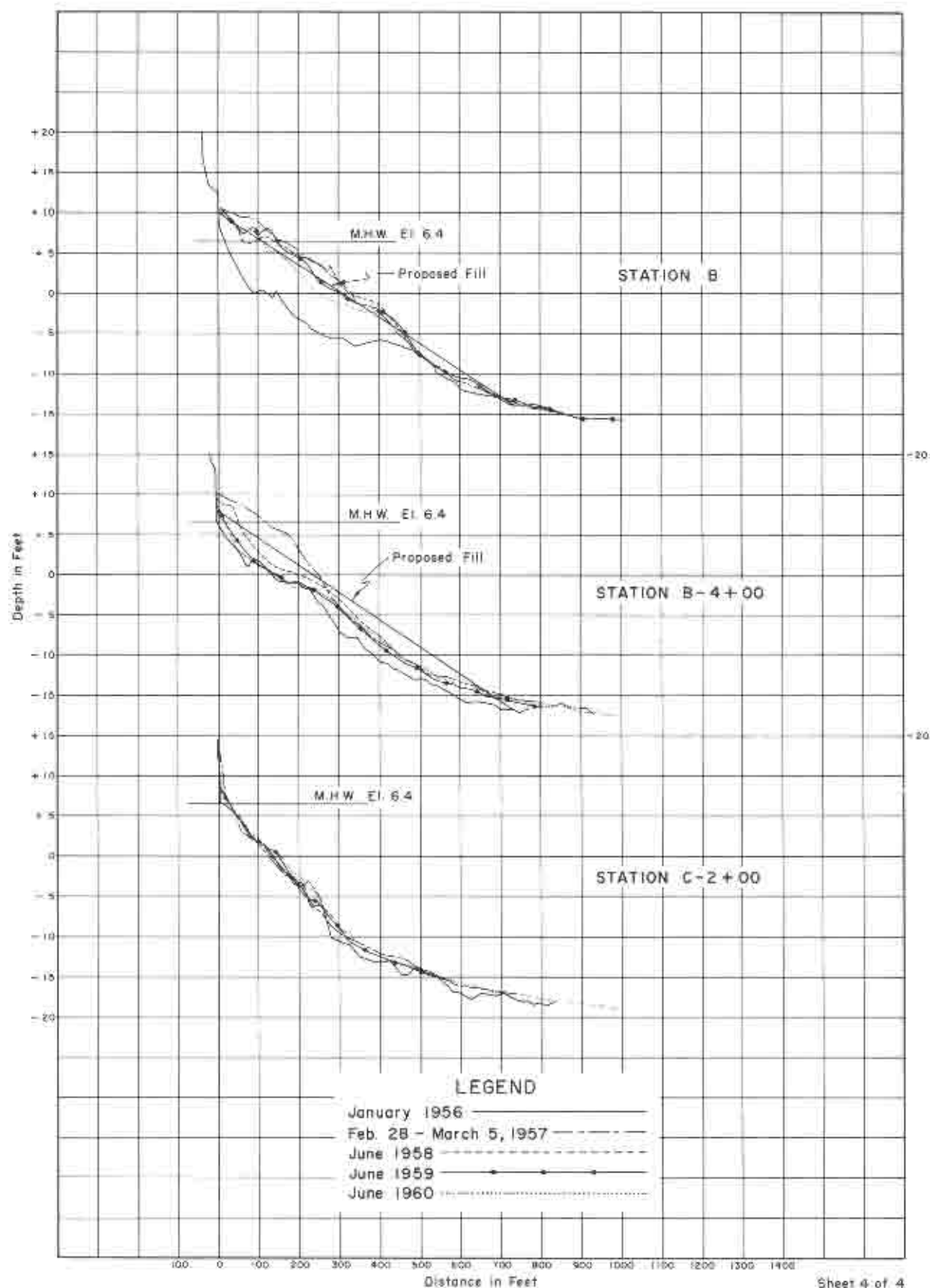


FIGURE 3. PROFILES - PROSPECT BEACH, CONNECTICUT

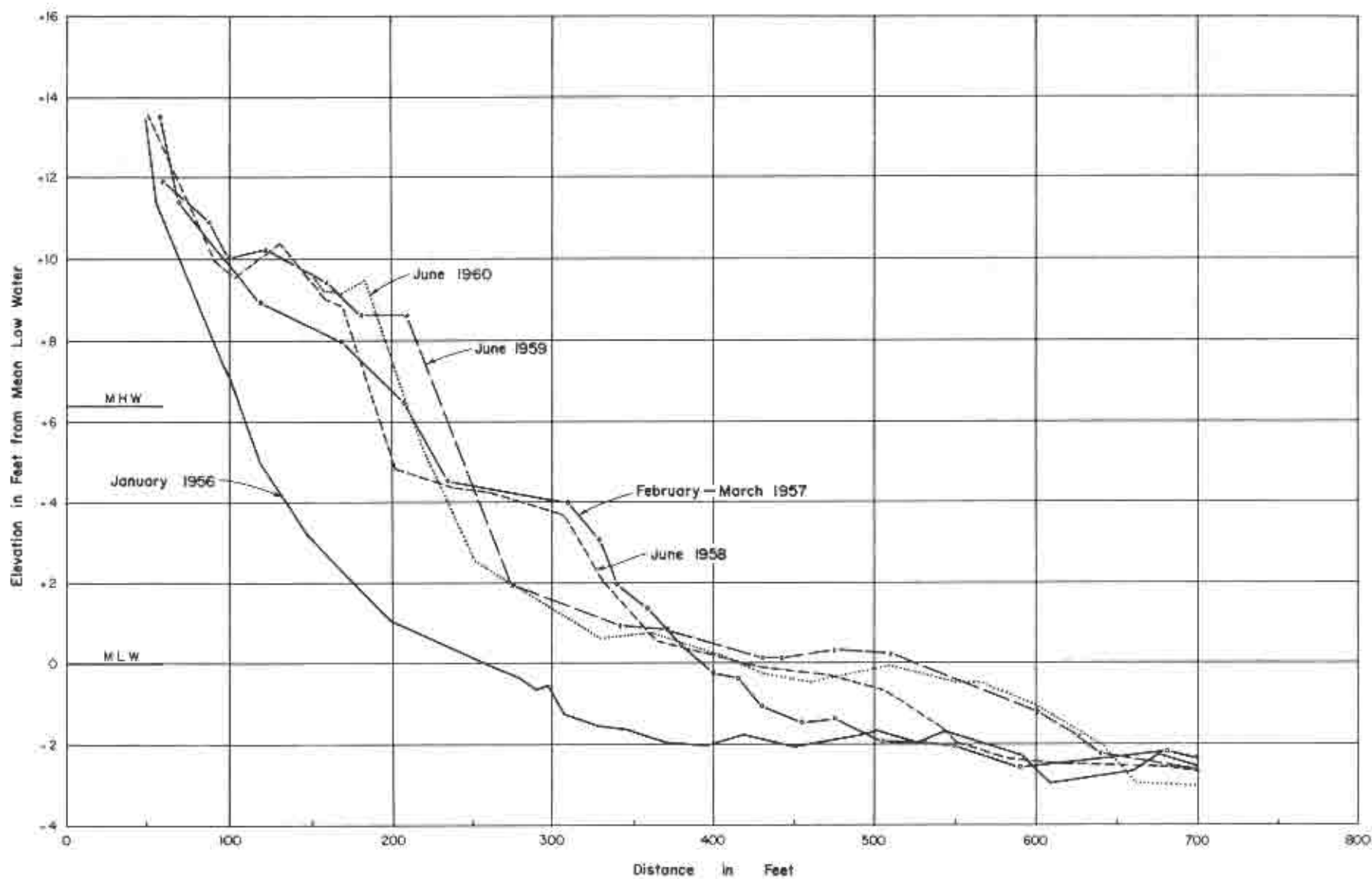


FIGURE 4. TYPICAL PLOT—COMPARATIVE BEACH SECTIONS

Figure 3, and an example of a plot of comparative beach sections is shown on Figure 4.

Only two sand samples were taken in 1951 before fill placement, however, twenty-nine samples were taken from the beach zone in 1957 after fill placement. During the resurvey of June 1960, thirty-four sand samples were taken from the beach and nearshore zones and nine core samples were taken in the borrow area. The surface sand samples were obtained by conventional procedures. The core samples in the borrow area were obtained by pushing a 1-3/4-inch diameter pipe into the bottom material and then recovering the material retained in the pipe. Locations of sand sampling and other pertinent data for all samples are given in Table 1.

Profiles of the groins were taken immediately after construction. There has been no maintenance of the groins to date, and no additional data have been obtained relative to those structures.

Analysis of Data

The profile data for each range surveyed from 1956 through 1960 are shown on Figure 3. These data show that the several profiles along the same range generally meet about 650 feet offshore. Between Ranges 0 and 44 the profiles meet at a depth of 3 to 4 feet below mean low water. South of Range 44 the profiles meet at an average depth of 14 feet below mean low water. Volumetric changes were computed from the comparative profile plots on Figure 3. The computations were made by considering the volume between the meeting point of profiles in the offshore zone, a common closure point at the landward edge of the beach, and the distance between ranges. In order to obtain a more detailed analysis of the net material movement in the area the beach and foreshore were divided into three zones as follow:

1. Above mean high water (ie. from MHW line on beach to seawall, revetment, or seaward edge of road).
2. Between planes of mean high and mean low water on the beach.
3. Below mean low water (ie. from MLW line on beach to where comparative profiles join in offshore zone).

The volumetric changes computed for each of these zones for each year from 1957 to 1960 are given in Table 2.

The data in Table 2 show that from March 1957 to June 1958 there was a gain of 9,700 cubic yards of material between Ranges 0 and 52 in the zone above mean high water, while there was a loss of 5,600 cubic yards in this zone south of Range 52. In the zone between mean high and mean low water during this same period there was a material gain of 3,700 cubic yards between Ranges 0 and 24, but losses southward thereof amounting to 14,400 cubic yards. For the zone below mean low water a gain of material throughout the study area is indicated. The gain in this latter zone amounted to

PROSPECT BRANCH
WEST HAVEN, CONN.
SILVER ANALYSIS

TABLE 1

Percent Copper than Stated Size

Range No.	Date	Sample Location	Elevation	Dist. off R.L.	5%	15%	25%	50%	75%	84%	95%	Percent Finest	Phi Mean	Std. Dev.	Skewness							
					mm.	Phi Units	mm.	Phi Units	mm.	Phi Units	mm.	Phi Units	mm.	Phi Units	mm.							
0+00	4/60	Berm	+10.4	10'	0.98	0.13	0.82	0.29	0.76	0.40	0.62	0.69	1.03	0.44	1.18	0.34	1.56	-	0.74	0.65	0.430	
"	"	MDV	+ 8.4	100'	0.90	0.15	0.67	0.58	0.56	0.84	0.42	1.25	0.32	1.64	0.28	1.84	0.22	2.25	-	1.21	0.61	-0.06
"	"	ME	+ 1.2	300'	"	"	1.80	-1.73	2.30	-1.80	1.05	-0.07	0.59	0.76	0.47	1.09	0.22	2.13	2.0	-0.42	1.51	-0.23
"	"	ME	0.0	300'	1.30	"	0.93	0.10	0.84	0.25	0.62	0.68	0.33	1.60	0.12	3.06	0.08	4.01	9.0	1.38	1.68	-0.66
"	"	Offshore	- 9.1	1760'	0.31	1.66	0.22	2.18	0.20	2.32	0.17	2.56	0.15	2.78	0.14	2.86	0.11	3.18	1.2	2.51	0.33	-0.15
11+00	"	Berm	+11.5	80'	0.90	0.15	0.68	0.56	0.57	0.81	0.40	1.32	0.27	1.89	0.22	2.18	0.25	2.64	0.4	1.37	0.81	-0.06
"	"	MDV	+ 7.8	180'	1.38	-0.66	1.03	-0.6	0.90	0.15	0.68	0.68	0.44	1.18	0.36	1.67	0.25	2.00	0.3	1.77	0.56	-0.04
"	"	ME	+ 1.2	300'	0.68	0.60	0.13	1.22	0.19	1.43	0.29	1.79	0.23	2.12	0.20	2.32	0.16	2.66	0.1	2.00	0.76	-0.16
"	"	Offshore	- 2.1	320'	0.58	0.79	0.39	1.36	0.33	1.60	0.23	2.12	0.18	2.47	0.18	2.64	0.13	2.94	0.5	2.00	0.66	-0.19
"	"	"	- 4.0	320'	0.93	0.38	0.54	0.89	0.42	1.25	0.29	1.79	0.20	2.32	0.18	2.67	0.11	2.84	0.2	1.68	0.79	-0.14
"	"	"	- 7.0	2160'	0.73	0.45	0.16	1.12	0.38	1.40	0.29	1.79	0.23	2.12	0.21	2.25	0.38	2.47	0.2	1.60	0.57	-0.38
26+00	7/60	"	-23.0	1500'	0.06	0.96	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	94.6	"	"	"
27+00	4/57	*Beach	"	"	2.01	-1.01	1.04	-0.06	0.87	0.70	0.52	0.94	0.28	1.84	0.23	2.12	0.25	2.74	"	1.03	1.09	0.08
28+00	7/80	*Core	+22.2	3500'	0.13	2.74	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	91.6	"	"	"
"	"	"	+23.4	"	0.15	2.74	2.11	3.18	0.09	1.67	"	"	"	"	"	"	"	"	69.3	"	"	"
29+00	2/57	*Beach	"	"	1.00	0.03	0.69	0.50	0.56	0.88	0.34	1.56	0.71	2.25	0.18	2.47	0.12	3.06	"	2.51	0.97	-0.05
29+00	1951	ME	"	"	"	"	"	"	"	"	6.70	-2.74	"	"	"	"	"	"	"	"	"	"
27+00	2/57	*Beach	"	"	1.60	-0.68	0.89	0.17	0.70	0.51	0.62	1.25	0.24	2.06	0.19	2.40	0.12	3.06	"	1.29	1.12	0.24
28+00	6/60	Berm	+20.4	80'	0.84	0.25	0.60	0.78	0.50	1.00	0.36	1.47	0.27	1.89	0.23	2.12	0.15	2.74	1.3	1.43	0.69	-0.06
"	"	MDV	+ 7.8	180'	0.92	0.12	0.64	0.64	0.55	0.85	0.42	1.25	0.30	1.56	0.30	1.74	0.24	2.06	"	1.19	0.55	-0.11
"	"	ME	0.0	400'	0.44	1.29	0.34	1.56	0.31	1.69	0.26	1.94	0.21	2.25	0.28	2.47	0.15	2.74	0.3	2.08	0.66	0.17
"	"	Offshore	- 5.0	1100'	0.52	0.94	0.62	1.25	0.39	1.34	0.34	1.56	0.29	1.79	0.26	1.94	0.20	2.32	0.1	1.59	0.15	0.06
"	"	*Core	-24.6	1500'	"	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	96.2	"	"	"
"	7/60	"	-25.8	"	0.18	2.47	0.11	3.18	0.62	4.01	"	"	"	"	"	"	"	"	75.5	"	"	"
"	"	"	-26.8	"	0.19	2.40	0.15	2.74	0.13	2.94	0.08	3.04	"	"	"	"	"	"	46.5	"	"	"
"	"	Offshore	- 7.1	1820'	0.59	0.76	0.43	1.22	0.18	2.10	0.32	1.84	0.26	1.94	0.23	2.12	0.14	2.47	0.1	1.67	0.65	0.07
29+13	2/57	*Beach	"	"	2.00	-1.00	1.80	-0.85	1.10	-0.40	0.89	0.17	0.62	0.89	0.40	1.18	0.19	2.40	"	0.17	1.02	0.00
30+10	"	"	"	"	2.30	-0.70	1.30	-0.38	0.80	0.30	0.51	0.97	0.32	1.64	0.23	2.12	0.23	2.94	"	0.87	1.25	-0.08
31+60	"	"	"	"	0.90	0.15	0.59	0.76	0.46	1.12	0.32	1.66	0.25	2.00	0.18	2.47	0.12	3.06	"	1.60	0.86	-0.03
32+00	6/60	*Core	-25.9	1520'	0.06	1.06	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	95.1	"	"	"
"	7/60	"	-26.7	1550'	0.13	2.94	0.09	3.47	"	"	"	"	"	"	"	"	"	"	79.4	"	"	"
32+80	4/57	*Beach	"	"	0.79	0.34	0.50	1.00	0.11	1.09	0.29	1.79	0.22	2.18	0.22	2.47	0.13	2.94	"	1.74	0.74	-0.07
33+60	"	"	"	"	1.80	-0.85	1.10	-0.14	0.81	0.27	0.52	0.94	0.30	1.74	0.23	2.12	0.14	2.84	"	0.99	1.13	0.04
35+20	"	"	"	"	1.25	-0.32	0.70	0.51	0.51	0.27	0.40	1.12	0.33	1.60	0.26	1.94	0.17	2.56	"	1.23	0.72	-0.13
36+40	"	"	"	"	1.50	-0.59	0.79	0.34	0.55	0.56	0.38	1.60	0.27	1.89	0.22	2.25	0.11	2.84	"	1.30	0.96	-0.10
37+00	"	"	"	"	1.85	-0.89	1.15	-0.80	0.80	0.32	0.60	0.74	0.35	1.51	0.25	2.00	0.15	2.74	"	0.90	1.30	0.15
"	"	"	"	"	0.72	0.47	0.54	0.89	0.41	1.29	0.29	1.79	0.23	2.12	0.20	2.32	0.16	2.64	"	1.61	0.72	-0.25
39+00	2/57	*Beach	"	"	2.30	-1.20	1.45	-0.54	0.94	0.09	0.50	1.00	0.34	1.56	0.26	1.94	0.15	2.74	"	0.79	1.24	-0.24
39+60	"	"	"	"	0.77	1.38	0.59	0.76	0.50	1.00	0.32	1.64	0.24	1.94	0.23	2.25	0.17	2.56	"	1.51	0.75	-0.17
41+00	"	"	"	"	0.70	0.51	0.34	1.56	0.29	1.79	0.23	2.22	0.17	2.56	0.14	2.86	0.09	3.12	"	2.20	0.64	0.13
41+00	6/60	Berm	+12.0	62'	0.56	0.84	0.44	1.15	0.39	1.34	0.40	1.24	0.29	2.22	0.28	2.47	0.16	2.84	0.4	1.75	0.67	0.13
"	"	MDV	+ 8.4	225'	0.94	0.09	0.34	0.84	0.53	0.92	0.19	2.36	0.31	1.89	0.27	1.89	0.21	2.25	"	1.27	0.63	-0.44
"	"	ME	0.0	400'	0.63	0.67	0.43	1.22	0.17	2.11	0.28	1.84	0.21	2.25	0.18	2.47	0.16	2.84	0.6	1.85	0.63	0.02
"	"	Offshore	- 6.6	560'	1.13	-0.30	0.90	0.37	0.66	0.60	0.44	1.18	0.21	2.25	0.13	2.94	0.06	4.00	9.3	1.63	1.11	0.34
"	"	"	- 7.4	1100'	0.45	2.03	0.43	1.22	0.42	1.29	0.38	1.67	0.30	1.74	0.28	1.94	0.19	2.40	0.5	1.58	0.36	0.31
49+90	1/57	*Beach	"	"	1.75	-0.81	0.54	0.08	0.83	0.67	0.46	1.12	0.32	1.64	0.25	2.00	0.17	2.56	"	1.05	0.66	-0.07
49+90	"	"	"	"	0.00	-0.59	2.30	-1.20	1.50	-0.59	0.80	0.35	0.58	0.79	0.30	1.74	0.18	2.47	"	0.87	1.47	0.08
50+00	"	"	"	"	1.30	-0.38	0.50	0.32	0.58	0.79	0.40	1.32	0.28	1.84	0.22	2.18	0.14	2.84	"	1.25	0.91	-0.08
50+70	"	"	"	"	1.70	-0.77	0.92	0.14	0.87	0.58	0.48	1.06	0.35	1.51	0.27	1.89	0.28	2.37	"	1.04	0.80	-0.08
51+30	"	"	"	"	1.10	-0.48	0.78	0.36	0.59	0.79	0.37	1.22	0.33	1.60	0.28	1.94	0.16	2.64	"	1.15	0.79	-0.09
51+70	"	"	"	"	1.00	3.00	0.66	0.90	0.53	0.92	0.37	1.43	0.25	2.00	0.28	2.47	0.12	3.06	"	1.54	0.94	0.12
52+13	2/57	ME	"	"	"	"	"	"	"	"	54.00	-2.75	"	"	"	"	"	"	"	"	"	"
52+60	2/57	*Beach	"	"	1.20	-0.26	0.60	0.74	0.44	1.18	0.28	1.84	0.17	2.56	0.14	2.86	0.08	3.64	"	1.79	1.05	-0.05
53+30	"	"	"	"	1.80	-0.85	0.98	0.23	0.72	0.47	0.48	1.06	0.40	1.12	0.30	1.74	0.18	2.40	"	0.85	0.56	-0.20
54+30	"	"	"	"	0.58	-0.79	0.16	1.17	0.29	1.79	0.22	2.18	0.16	2.64	0.14	2.84	0.09	3.47	"	2.16	0.69	-0.03
56+00	4/60	Berm	+10.5	208'	0.86	0.22	0.59	0.76	0.51	0.97	0.37	1.43	0.26	1.94	0.22	2.32	0.17	2.56	1.4	1.47	0.71	0.04
"	"	MDV	+ 6.4	310'	1.57	-0.65	1.22	0.00	0.84	0.25	0.58	0.79	0.42	1.25	0.17	1.43	0.28	1.84	"	0.72	0.72	-0.10
"	"	ME	+ 1.5	2579'	1.14	-0.19	0.76	0.10	0.63	0.67	0.41	1.29	0.29	1.79	0.26	2.06	0.18	2.47	"	1.23	0.81	-0.07
"	"	Offshore	-11.7	1000'	0.27	1.86	0.09	3.47	0.67	3.81	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	66.0	"	"	"
"	"	"	-17.3	1390'	0.09	3.47	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	Net Sieved	92.8	"	"	"
56+90	2/57	*Beach	"	"	1.70	-0.77	0.30	0.35	0.40	0.58	0.48	1.06	0.34	1.56	0.27	1.89	0.17	2.56	"	1.02	0.87	-0.05
56+90	"	"	"	"	1.60	-0.68	0.30	0.15	0.70	0.52	0.50	1.00	0.43	1.22	0.35	1.51	0.25	2.00	"	0.81	0.46	-0.25
59+50.8	"	"	"	"	1.20	-0.26	0.73	0.45	0.59	0.76	0.45											

TABLE 2

PROSPECT BEACH, CONN.
Volumetric Change - Thousand Cubic Yards

	1957 - 1958			1958 - 1959			1959 - 1960			1957 - 1960			
Sta.	Above MHW	MLW MHW	Below MLW	Above MHW	MLW MHW	Below MLW	Above MHW	MLW MHW	Below MLW	Above MHW	MLW MLW	Below MLW	Net
0+00	1.5	2.4	-0.4	0.2	-0.5	-0.1	1.3	2.7	-0.9	3.0	4.6	-1.4	6.2
4+0	2.5	2.4	-0.6	0.8	-1.2	0.4	1.5	2.5	-1.1	4.8	3.7	-1.3	7.2
8+0	0.7	-0.8	2.8	-0.3	-2.1	2.0	0.5	1.2	-0.5	0.9	-1.7	4.3	3.5
14+0	-0.4	-0.5	1.2	-0.1	0.3	1.3	0.2	-0.4	-0.3	-0.3	-0.6	2.2	1.3
16+0	0	-0.1	0.9	0.4	0.5	1.3	0.1	-1.1	-0.1	0.5	-0.7	2.1	1.9
18+0	0.3	0	1.6	0.5	-0.3	0.7	-0.5	-1.7	0.1	0.3	-2.0	2.4	0.7
20+0	0.6	0.3	3.4	-0.3	-2.7	-0.2	-0.5	-1.6	-0.2	-0.2	-4.0	3.0	-1.2
24+0													
Subtot.	+5.2	+3.7	+8.9	+1.2	-6.0	+5.4	+2.6	+1.6	-3.0	+9.0	-0.7	+11.3	+19.6
24+0	1.0	-0.3	3.5	-1.1	-3.2	0.3	0.1	-0.3	-0.8	0.0	-3.8	3.0	-0.8
28+0	1.1	-0.5	3.1	0.4	-0.4	2.1	-0.4	-1.7	-1.1	1.1	-2.6	4.1	2.6
32+0	0.9	-1.0	2.1	1.1	0.6	3.0	-0.2	0	-1.3	1.8	-0.4	3.8	5.2
36+0	0	-0.9	0.6	0.1	0.4	1.5	0.1	0.6	-0.3	0.2	0.1	1.8	2.1
38+0	-0.2	0.2	1.0	0	0.9	1.6	0.4	0.2	0.4	0.2	1.3	3.0	4.5
40+0	0.1	-0.3	0.3	0.2	1.8	4.8	1.5	-1.3	-1.0	1.8	0.2	4.1	6.1
44+0	1.5	-0.3	-1.7	0	-0.6	8.0	0.8	-1.3	-2.7	2.3	-2.2	3.6	3.7
48+0	0.1	-0.7	-0.2	0.4	-3.3	6.5	-1.3	-1.4	-3.1	-0.8	-5.4	3.2	-3.0
52+0													
Subtot.	+4.5	-3.8	+8.7	+1.1	-3.8	+27.8	+1.0	-5.2	-9.9	+6.6	-12.8	+26.6	+20.4
Total	+9.7	-0.1	+17.6	+2.3	-9.8	+33.2	+3.6	-3.6	-12.9	+15.6	-13.5	+37.9	+40.0
52+0	-1.7	-3.0	0.2	0.4	-3.3	2.5	-2.4	-3.4	-4.2	-3.7	-9.7	-1.5	-14.9
56+0	-0.6	-0.3	0.1	0.2	-0.6	0.4	-0.5	-1.2	-1.0	-0.9	-2.1	-0.5	-3.5
"B"	-2.8	-4.1	1.2	-0.0	-2.8	-3.4	-0.5	-0.1	0.4	-3.3	-8.8	-1.8	-13.9
B+400	-0.5	-3.2	1.3	-0.5	-1.3	-3.1	0	-0.5	1.2	-1.0	-5.0	-0.6	-6.6
"C"													
Subtot.	-5.6	-10.6	+2.8	+0.1	-7.8	-3.6	-3.4	-7.2	-3.6	-8.9	-25.6	-4.4	-38.9
Gr. Tot.	+4.1	-10.7	+20.4	+2.4	-17.6	+29.6	+0.2	-10.8	-16.5	+6.7	-39.1	+33.5	+1.1

20,400 cubic yards. Thus the survey data for the first year after placement of fill indicate a net gain of material for the entire study area of 13,800 cubic yards.

Between June 1958 and June 1959 virtually all losses were confined to the zone between the planes of mean high and mean low water. Loss of material in this zone along the entire length of shore amounted to 17,600 cubic yards. There was a small gain of material in the zone above mean high water amounting to 2,400 cubic yards while the zone below mean low water gained 33,200 cubic yards of material between Ranges 0 and 52, and lost 3,600 cubic yards from the area south of Range 52. The net material movement for the three zones between the study limits for the second year was a gain of 14,400 cubic yards. The general movement of material during the second year after placement of fill was similar to that of the first year in that virtually all losses occurred in the zone between mean high and mean low water while the gains were confined almost entirely to the zone below mean low water.

During the 12-month period between June 1959 and June 1960, some accretion occurred in the zone above mean high water between Ranges 0 and 52, and also in the zone between mean high and mean low water from Range 0 to Range 14; however, elsewhere in the area material losses were indicated. In the zone above mean high water there was a gain of 3,600 cubic yards of material in the area north of Range 52, while south of this range losses amounted to 3,400 cubic yards. Between mean high and mean low water, accretion amounted to 6,400 cubic yards from Range 0 to Range 14, however, there was a loss of 17,200 cubic yards throughout the remainder of the zone. Losses occurred along the entire length of the zone below mean low water, the losses being greater at the southern end of the study area and reducing toward the north. The material lost from this zone from June 1959 to June 1960, amounted to 16,500 cubic yards and the net loss for all three zones amounted to 27,100 cubic yards.

The data in Table 2, for the 3-year period March 1957 to June 1960, show a gain of 15,600 cubic yards of material in the zone above mean high water between Ranges 0 and 52, and a loss of 8,900 cubic yards south of Range 52. Losses totaling 39,100 cubic yards occurred along the entire length of the zone between mean high and mean low water. In the zone below mean low water there was a gain of 37,900 cubic yards of material between Ranges 0 and 52, and a loss of 4,400 cubic yards in this zone south of Range 52. The tabulated data on material movement also show that practically all net losses of fill have occurred at the southern end of the beach. There was some loss of fill between the high and low water lines along other sections of the beach; however, along the beach as a whole accretion exceeded erosion. Over the entire beach and foreshore south of Range 52, net losses amounted to 38,900 cubic yards over the period of record, or about 13,000 cubic yards per year. During this same period north of Range 52 there was a gain of 40,000 cubic yards or about 13,300 cubic yards per year. The net accretion for the entire area, between limiting ranges, was 1,100 cubic yards or about 370 cubic yards per year.

Changes in the mean high and mean low water lines on the beach for the period of record are shown graphically on Figures 5 and 6, respectively. The high water line changes consisted generally of recession at the south end of the beach with an advance immediately adjacent to it, due to the northward movement of the fill material. Along the central part of the study area there were minor changes of the mean high water line, the data showing mostly recession while the changes at the north end of the beach reflect general advance. The low-water-line changes followed a similar pattern, however; between 1959 and 1960 there was recession at this elevation both at the north and south ends of the beach.

Soundings of the borrow area were made in January 1957 before dredging and in February of the same year after dredging. These data were used to obtain an approximation of the quantity of material excavated. During the resurvey of June 1960 the borrow area was sounded along nine ranges to obtain an indication of the rate of shoaling. Comparative profiles of the offshore borrow area have been plotted from the survey data and are shown on Figure 3. The ranges covering the borrow area are 16, 18, 20, 24, 28, 32 and 36. Computation of bottom changes indicates that approximately 437,700 cubic yards of material were originally dredged from the borrow area, and that between March 1957 and June 1960 shoaling in the borrow pit amounted to about 25,000 cubic yards or at an average annual rate of about 8,300 cubic yards.

The sand sample data in Table 1 for the 1960-survey show that north of Range 44 samples had median diameters ranging from 0.17 to 1.05 millimeters, and south of Range 44 the median diameters ranged from 0.28 to 0.58 millimeter. The spread of these values is in very close agreement with that of median diameters of samples taken in 1957 along the ranges in the beach zone immediately after the fill was placed. The 1957-samples show median diameters ranging from 0.22 to 0.89 millimeter. The size analysis of the core samples obtained in the borrow pit in 1960 indicates that material composing the bottom of the pit in 1960 averages 80 percent finer than 0.062 millimeter.

Cumulative particle size distribution curves and computed composite curves have been drawn for these two beach segments for 1960 and also for the overall beach for 1957, using the method given by Krumbein.* To facilitate statistical analysis, phi-unit values of the sand particle sizes are used. Table 3 lists the phi-unit equivalents for some of the more commonly used standard sieve-mesh openings. A summary of observed composite size-frequency data and computed composite curve data are given in Tables 4 and 5 respectively, and the corresponding plotted curves are shown on Figures 7, 8, and 9. The phi standard deviation for the computed curves was determined to be 1.09, 0.95 and 0.84, respectively. This shows the relatively small variation in values of standard deviation. Comparative plots of the observed composite curves are shown on Figure 10 and of computed composite curves on Figure 11. The composite curves show close agreement in values of the phi mean diameters. These values from computed composite curves are 1.22 for the samples taken

* Krumbein, W. C. - "A Method For Specification of Sand For Beach Fills", Beach Erosion Board, Technical Memorandum No. 102, U. S. Army Corps of Engineers, 1957.

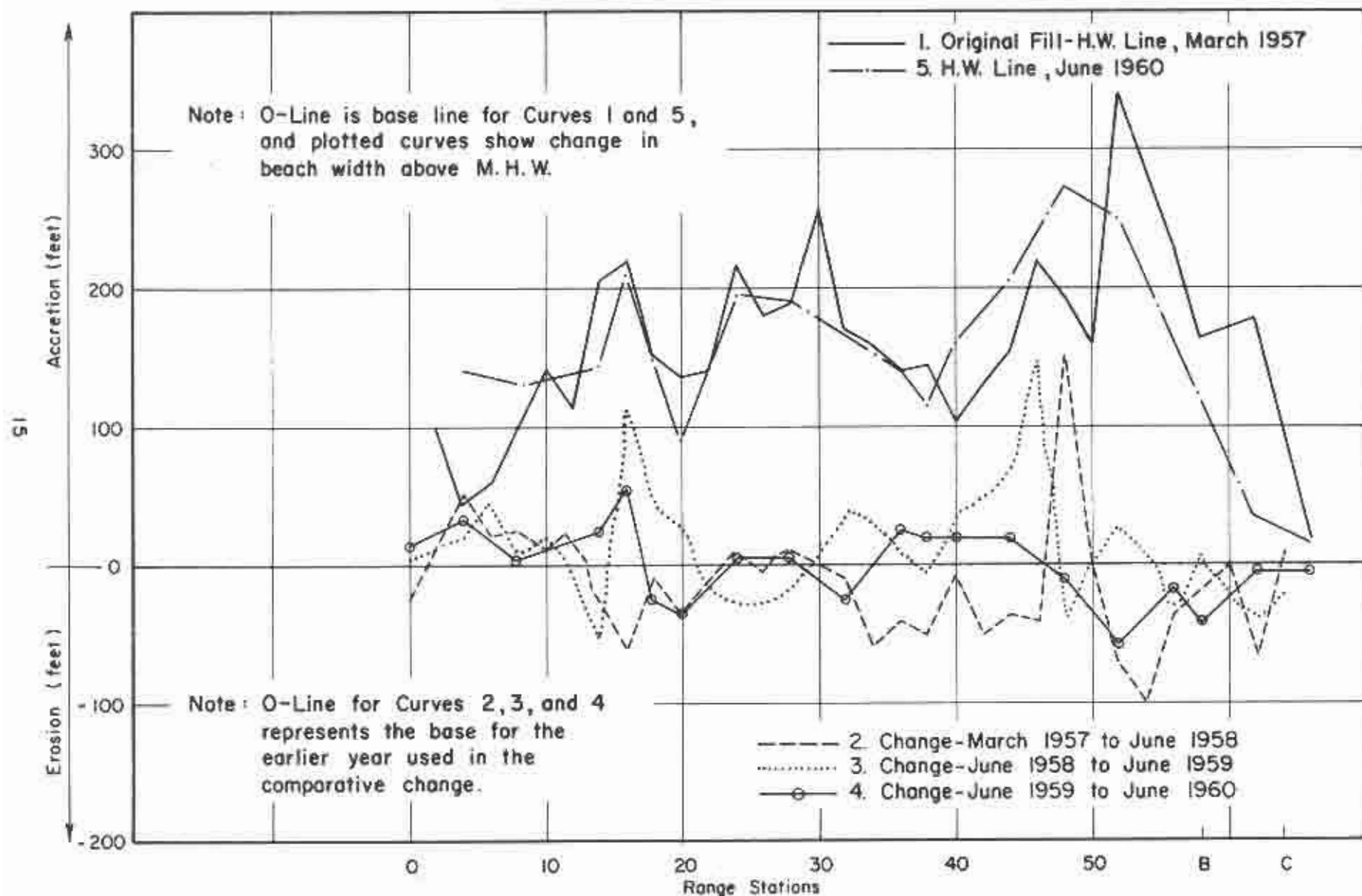


FIGURE 5. HIGH WATER SHORE LINE CHANGES, PROSPECT BEACH, CONN.

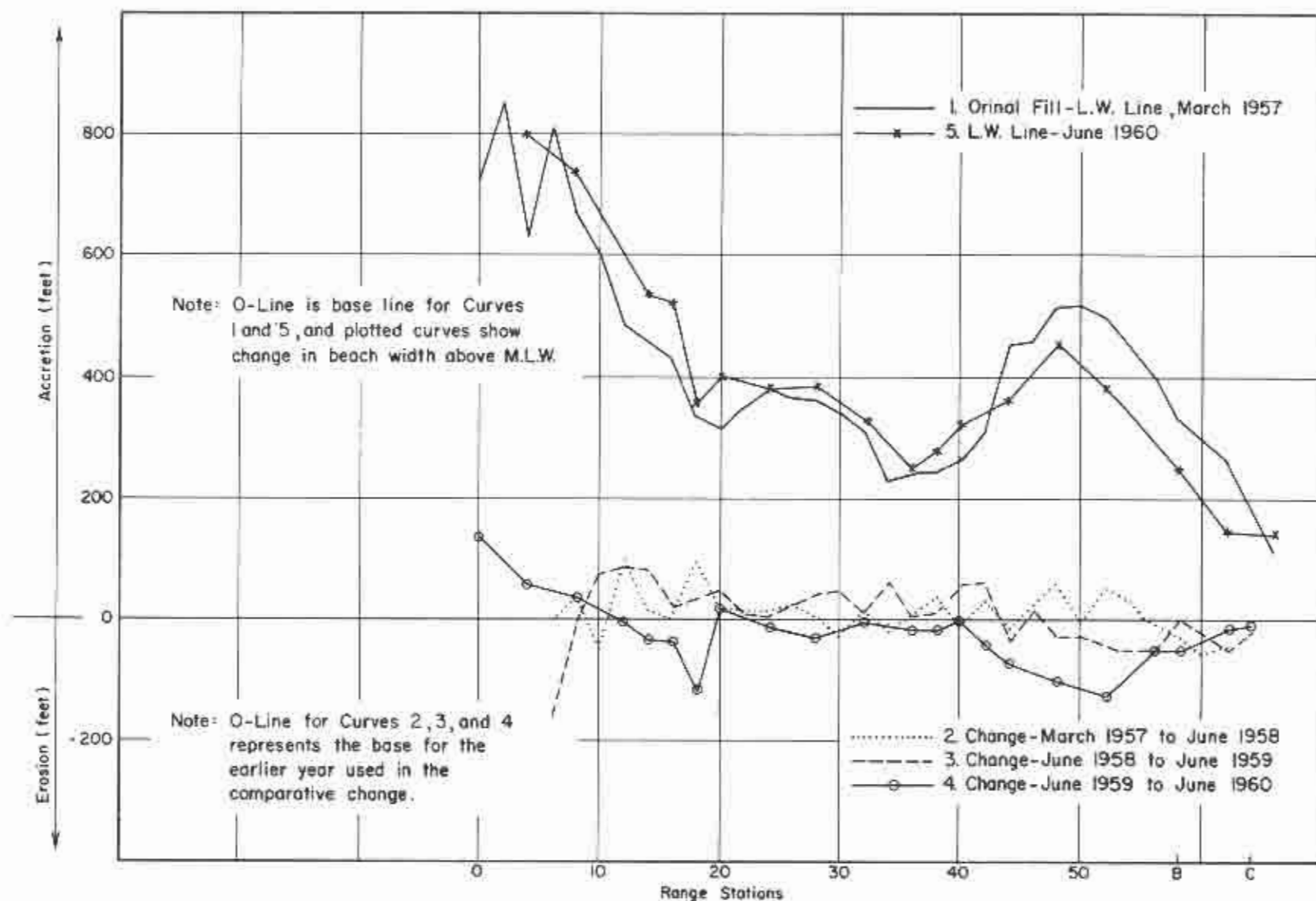


FIGURE 6. LOW WATER SHORE LINE CHANGES, PROSPECT BEACH, CONN.

TABLE 3
 PHI VALUES OF STANDARD SIEVE MESHES
 (ASTM Sieve Scale)

<u>Mesh Number</u>	<u>Opening, Millimeters</u>	<u>Phi-Unit Value</u>
5	4.00	-2.00
6	3.36	-1.75
7	2.83	-1.50
8	2.38	-1.25
10	2.00	-1.00
12	1.68	-0.75
14	1.41	-0.50
16	1.19	-0.25
18	1.00	0.00
20	0.84	0.25
25	0.71	0.50
30	0.59	0.75
35	0.50	1.00
40	0.42	1.25
45	0.35	1.50
50	0.297	1.75
60	0.250	2.00
70	0.210	2.25
80	0.177	2.50
100	0.149	2.75
120	0.125	3.00
140	0.105	3.25
170	0.088	3.50
200	0.074	3.75
230	0.062	4.00
270	0.053	4.25
325	0.044	4.50

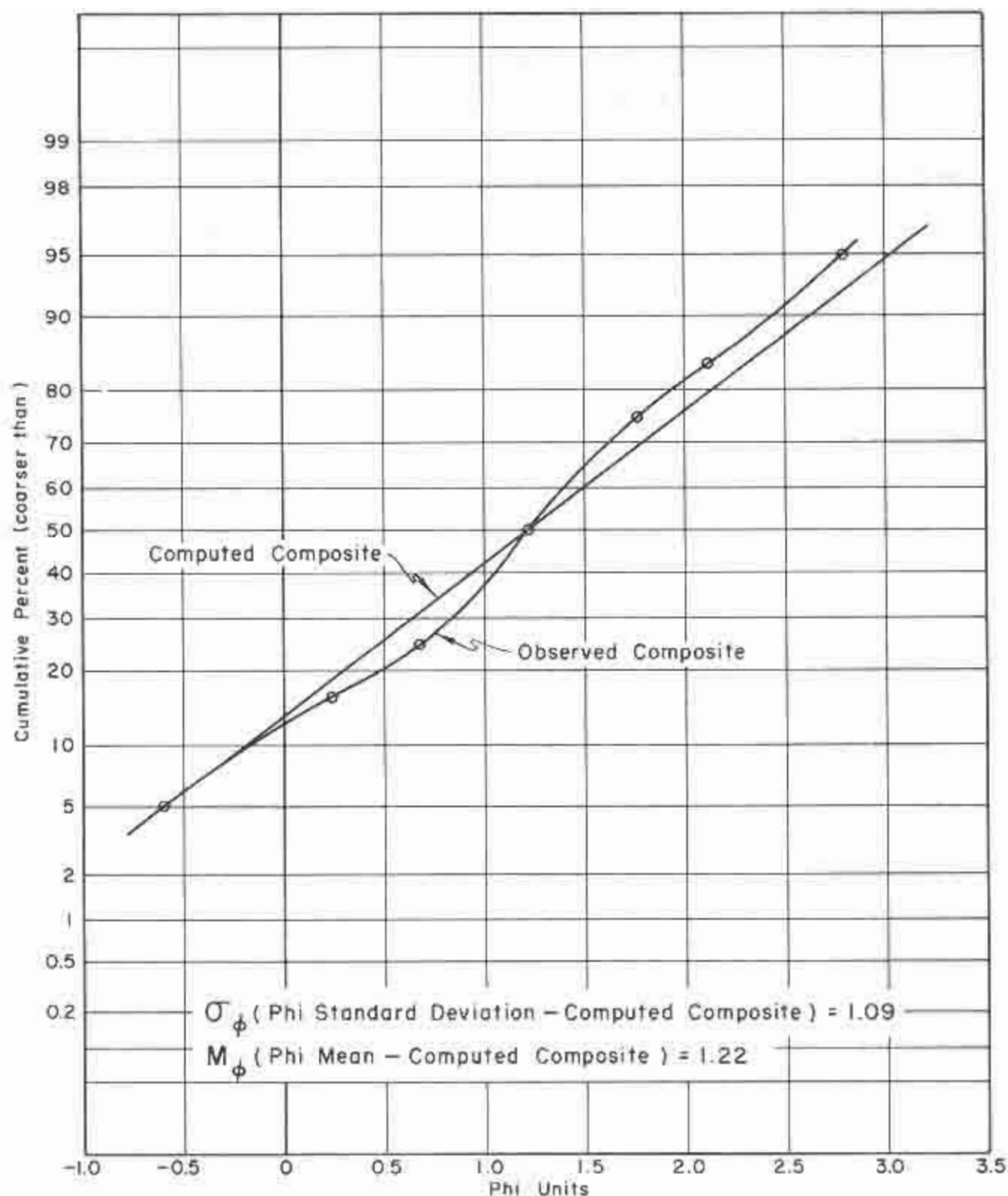


FIGURE 7. OBSERVED AND COMPUTED COMPOSITE DISTRIBUTION CURVES FOR ORIGINAL FILL (ENTIRE BEACH)
1957 COMPOSITE SAND SAMPLES

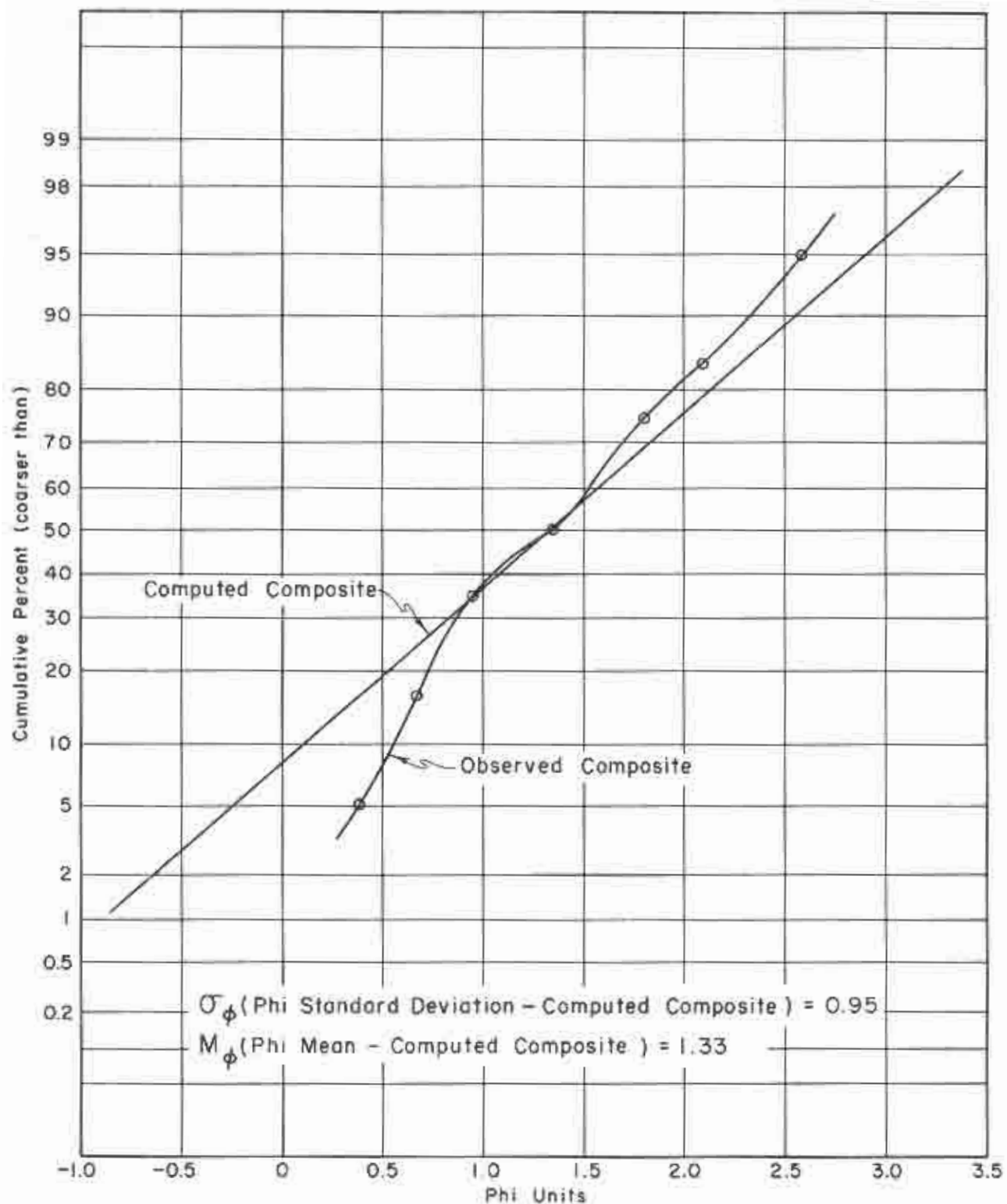


FIGURE 8. OBSERVED AND COMPUTED COMPOSITE DISTRIBUTION CURVES FOR AREA NORTH FROM RANGE 44 + 00
1960 COMPOSITE SAND SAMPLES

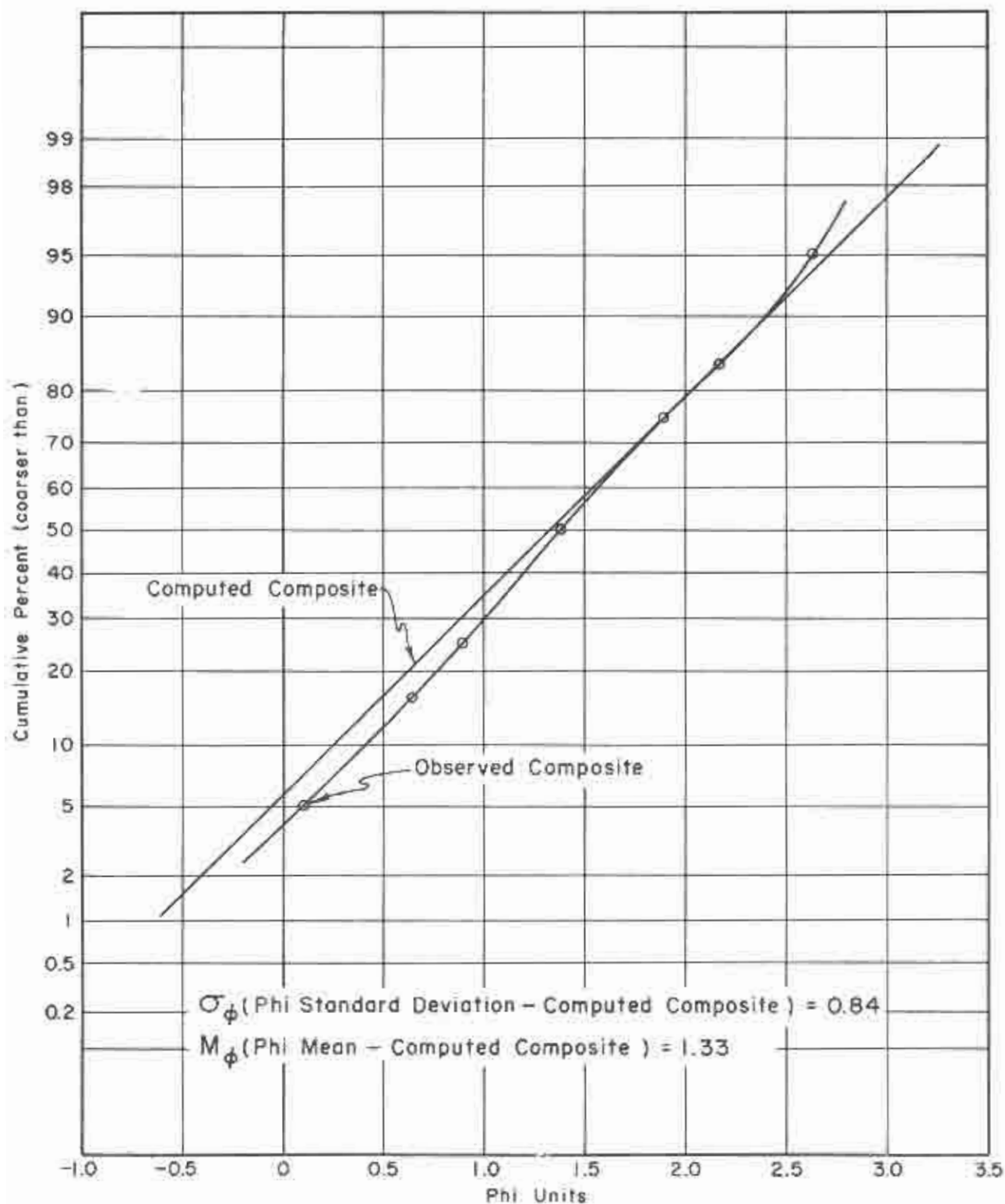


FIGURE 9. OBSERVED AND COMPUTED COMPOSITE DISTRIBUTION CURVES FOR AREA SOUTH FROM RANGE 44 + 00
1960 COMPOSITE SAND SAMPLES

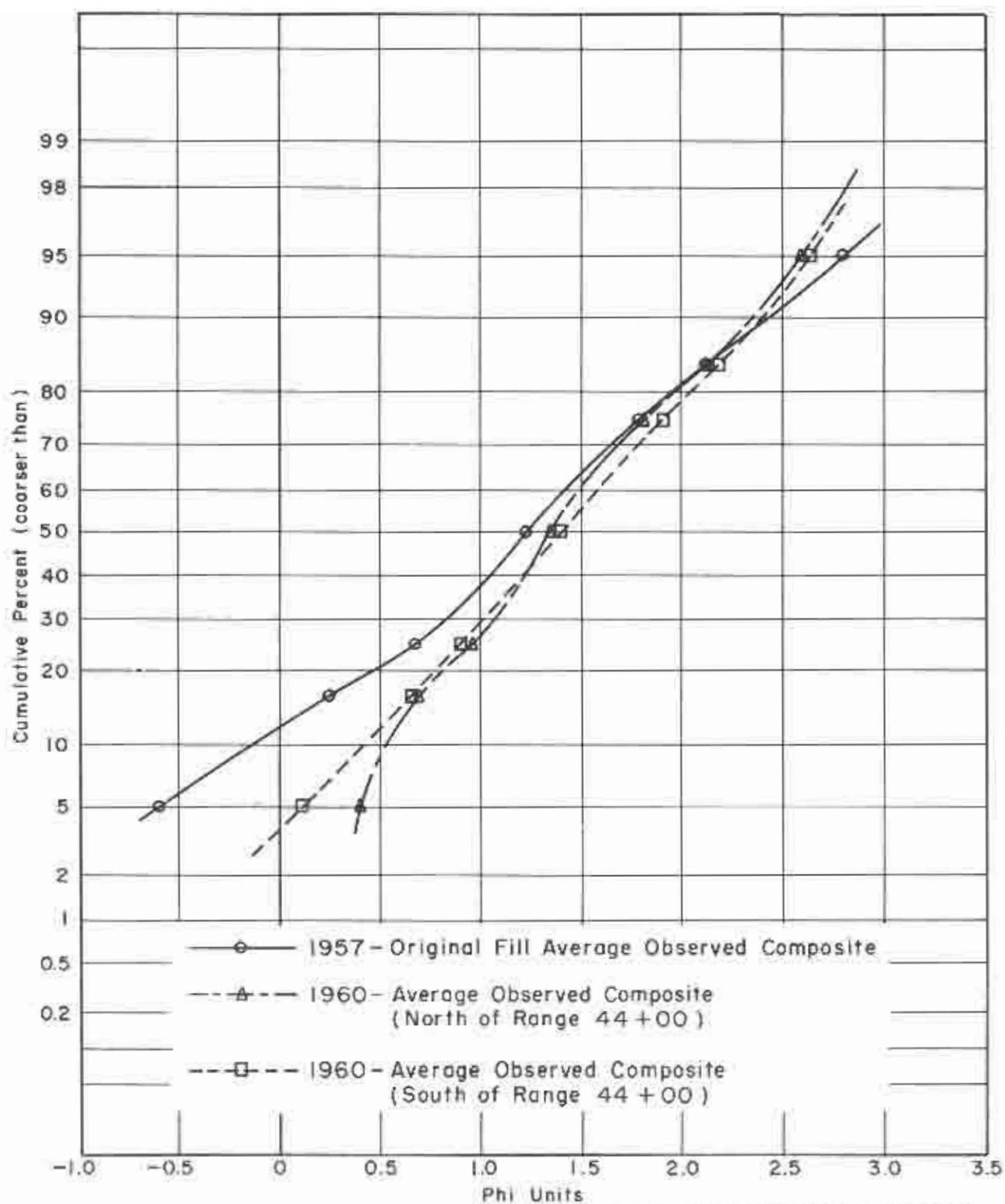


FIGURE 10. COMPARISON OF OBSERVED COMPOSITE CURVES

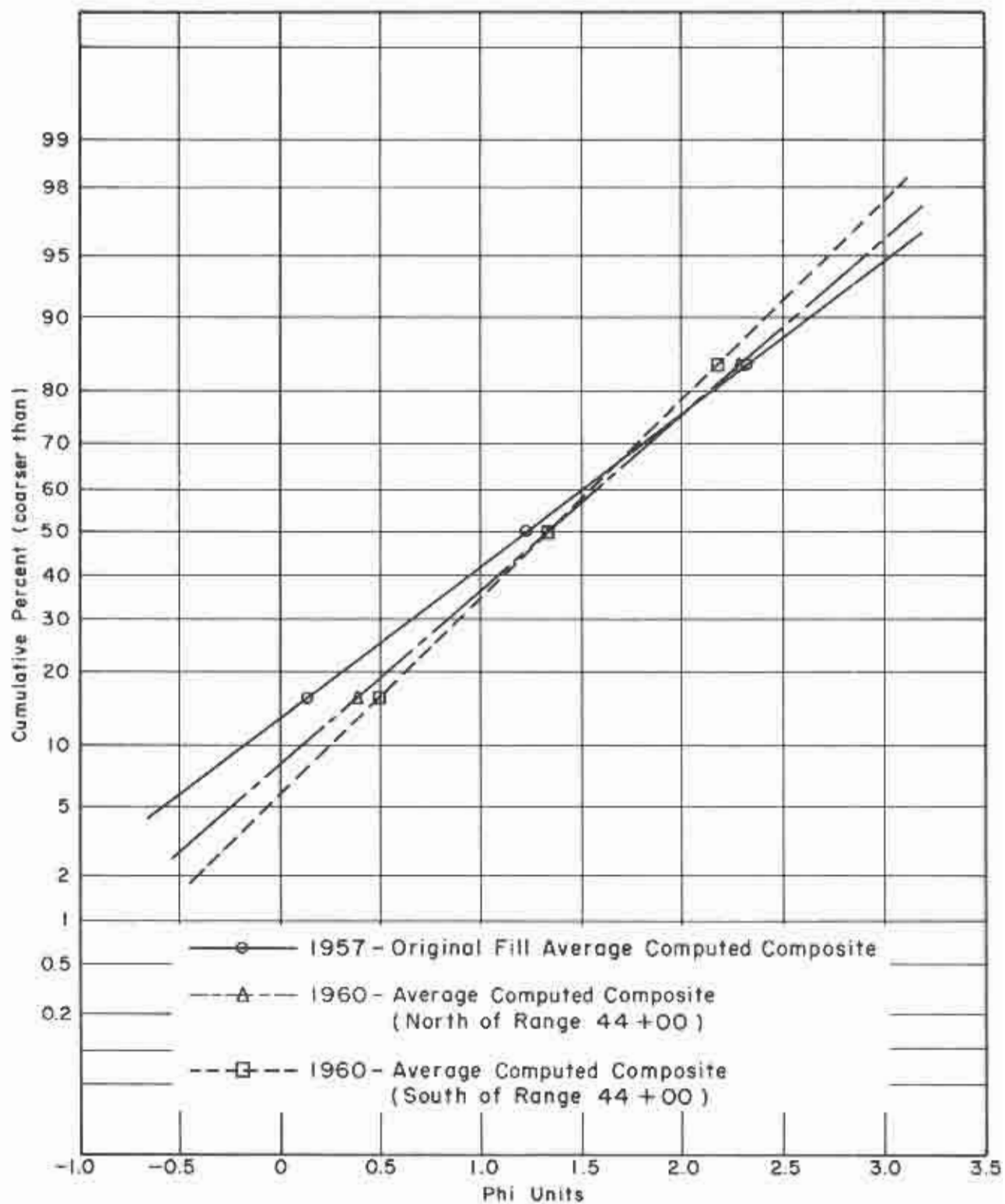


FIGURE II. COMPARISON OF COMPUTED COMPOSITE CURVES

in 1957 after placement of the fill, and 1.33 for the surface samples taken in 1960 both north and south of Range 44.

TABLE 4
SUMMARY OF DATA FOR OBSERVED
COMPOSITE SAND SAMPLES

Percent Coarser	Phi Values		
	1957 Original Fill	1960 North of Range 44	1960 South of Range 44
5	-0.60	0.39	0.10
16	0.24	0.67	0.65
25	0.67	0.95	0.89
50	1.22	1.35	1.38
75	1.77	1.80	1.90
84	2.12	2.10	2.18
95	2.80	2.58	2.63

The similarity of the three composites as shown by the close relation of their phi mean and standard deviations indicates that the composition of the samples taken in 1960 was almost identical to those taken in 1957.

Discussion

The survey data covering the period March 1957 to June 1960 indicate that about 39,000 cubic yards of material has been transported from the beach face between the planes of mean high and mean low water. About 65 percent of this volume was transported out of the southerly 1,400-foot segment of shore under study, about 30 percent from the central 2,800 feet of shore, and about 5 percent from the northerly 2,200 feet of shore. For the respective southerly, central, and northerly shore segments, the beach zone above mean high water and the offshore zone showed erosion in the southerly segment and thence gradual accretion toward the north; the net material movement between study limits for the zones above mean high water and offshore from mean low water being accretion about equal to the volume transported from the beach zone between mean high and mean low waters. The 1960-survey was in less detail as compared to the 1957-survey and this factor introduces some error in the volumetric computations; however, the indicated quantitative material movements are undoubtedly of the right order of magnitude. The computations would thus indicate that there has been a general movement of material from the southerly reach of the study area, and that these eroded materials are being transported to the north and gradually deposited there. Concurrently with this action some material was being transported from the beach zone to the zone seaward of the mean low water line, in the central and northerly portion of the study area. Since the quantity of material eroded from the beach zone about equals

Table 5

Computation
of
Computed Composite Curve

$$\sigma_{comp}^2 = \frac{(B-A)^2}{12} + \frac{(B-A)^2}{6(7-1)}$$

$$\phi_{50} = \frac{B+A}{2}$$

$$\phi_{16} = \frac{B+A}{2} - \sigma_{comp}$$

$$\phi_{84} = \frac{B+A}{2} + \sigma_{comp}$$

where σ_{comp}^2 is the variance of computed composite curve, σ^2 is the mean variance of the individual distributions. B and A are the extreme phi means and n is the number of samples in the set.

Data for Computed Composite Curve

Original Fill 1957

Range	Phi Mean		B-A	$\frac{B+A}{2}$	σ^2
	B	A			
29+13		0.17			
32+80	1.74		1.57	0.96	
41+00	2.20				
49+50		0.27	1.93	1.24	
54+30	2.16				
B4		0.75	1.41	1.46	
Total			4.91	3.66	
Average			1.64	1.22	0.9411

Accretion Area 1960

Range	Phi Mean		B-A	$\frac{B+A}{2}$	σ^2
	B	A			
0+00	2.51	-0.42	2.93	1.05	
14+00	2.00	0.72	1.28	1.36	
28+00	2.02	1.19	0.83	1.60	
Total			5.04	4.01	
Average			1.68	1.33	0.6330

Table 5 (Cont'd.)

Erosion Area 1960

Range	Phi B	Mean A	B-A	$\frac{B+A}{2}$	σ^2
44+00	1.85	1.27	0.58	1.56	
56+00	<u>1.47</u>	<u>0.72</u>	<u>0.75</u>	<u>1.10</u>	
Total			<u>1.33</u>	<u>2.66</u>	
Average			0.66	1.33	0.6486

Original Fill 1957
Computed Composite

$$\begin{aligned}\sigma_{\text{Comp.}}^2 &= .9411 + \frac{2.6896}{12} + \frac{2.3409}{150} \\ &= .9411 + 0.2241 + 0.0179 = 1.183 \\ \sigma_{\text{Comp.}} &= 1.0877\end{aligned}$$

$$\begin{aligned}\phi_{50} &= \frac{B+A}{2} = 1.22 \\ \phi_{16} &= \frac{B+A}{2} - \sigma_{\text{Comp.}} = 1.22 - 1.09 = 0.13 \\ \phi_{84} &= \frac{B+A}{2} + \sigma_{\text{Comp.}} = 1.22 + 1.09 = 2.31\end{aligned}$$

Computed Composite
Accretion Area 1960
North of Range 44

$$\begin{aligned}\sigma_{\text{Comp.}}^2 &= 0.6330 + \frac{2.822}{12} + \frac{2.822}{78} \\ &= 0.6330 + 0.2360 + 0.0362 = 0.9044 \\ \sigma_{\text{Comp.}} &= 0.9510\end{aligned}$$

$$\begin{aligned}\phi_{50} &= \frac{B+A}{2} = 1.33 \\ \phi_{16} &= \frac{B+A}{2} - \sigma_{\text{Comp.}} = 1.33 - 0.95 = 0.38 \\ \phi_{84} &= \frac{B+A}{2} + \sigma_{\text{Comp.}} = 1.33 + 0.95 = 2.28\end{aligned}$$

Erosion Area 1960
South of Range 44

$$\begin{aligned}\sigma_{\text{Comp.}}^2 &= 0.6486 + \frac{0.4356}{12} + \frac{0.4356}{36} \\ &= 0.6486 + 0.0363 + 0.0121 = .6970 \\ \sigma_{\text{Comp.}} &= 0.8349\end{aligned}$$

$$\begin{aligned}\phi_{50} &= \frac{B+A}{2} = 1.33 \\ \phi_{16} &= \frac{B+A}{2} - \sigma_{\text{Comp.}} = 1.33 - 0.84 = 0.49 \\ \phi_{84} &= \frac{B+A}{2} + \sigma_{\text{Comp.}} = 1.33 + 0.84 = 2.17\end{aligned}$$

that accreted in the zones above mean high water and seaward of mean low water in the central and northerly sections, and even though the erosion and accretion patterns are not constant throughout the study limits, there apparently has been no net loss of material from the study area to June 1960. These data would also indicate that of the total fill placed on the beach in 1957 a net of only about 9 percent had been transported from its zone of placement, that being the 39,100 cubic yards lost from the zone between mean high and mean low water. It is, of course, probable that a greater percentage of the placed fill has actually been moved by the littoral forces and redistributed in the same beach and bottom zones; however, the surveys were not made at sufficiently close time intervals to determine to what extent this process may have taken place.

Comparative high water shore line positions, as developed from the survey data, show that there was an average beach width above mean high water of about 45 feet within study limits immediately prior to placement of the beach fill. After placement of the fill in 1957 the beach width above mean high water averaged about 175 feet. This average figure includes the added width provided at the southerly end of the study area. In this beach sector the maximum beach width after filling was about 340 feet at Range 52, however, the width reduced to about 200 feet within several hundred feet north and south of Range 50. In June 1960 the average beach width for the study area was about 150 feet. In the 3-year period there was an average reduction in width of about 25 feet or an average reduction of about 8 feet annually. The rate of reduction of beach width at the southerly end of the fill was about twice the average for the entire study area. A higher rate of erosion for this sector was expected since this area was intended to act as the primary feeder beach for the shore to the north, and also because the fill extended into deeper water, and hence was subjected to more direct wave attack. Maintenance of a beach width above mean high water of 100 feet was contemplated under the authorized project for Prospect Beach. Thus for the 3-year period of study the beach width has been substantially greater than project dimensions. Based on the rate of recession for the 3-year period after placement of fill, and if no additional fill is placed on the beach, the width of the beach would be reduced below the recommended project width by about 1965 or 1966.

The volumetric computations and data developed for depicting shoreline changes indicate that the greatest adjustment of the fill material occurred in the first year after the fill was placed. The losses from between the planes of mean high and mean low water from 1959-60 were significantly less than from 1958-59. These data tend to indicate the littoral processes of the area have or will reach a more stable condition and the data may reflect the average annual losses from this zone that may be expected in the immediate future. Based on presently analyzed data there would be an annual average loss from between the planes of mean high and mean low water of about 13,000 cubic yards and the mean high water line would recede at an average of about 8 feet per year. Requirements for average annual maintenance of the beach fill could be based on the analysis of the data collected to date.

Analysis of the sand samples taken along profiles in June 1960 show that the composite of these samples is very nearly the same as the composite of

samples taken from the beach zone above mean low water in March 1957. The latter samples would represent the characteristics of the original fill material. These comparative size analysis data indicate that extensive sorting of the sediments composing the outer layers of the fill has taken place over the 3-year period. This would be additional evidence that the foreshore and bottom slopes of the study area have reached some degree of stability and that the overall rate of material movement in the littoral zone has reached relative stability.

The 1957-survey data show that about 437,700 cubic yards of material was dredged from the borrow area located in the offshore zone. Comparison of the 1957 and 1960-survey data show that about 25,000 cubic yards of material accumulated in the borrow pit during that 3-year period. The accumulation of material in the pit was fairly uniform throughout the area. This is an annual average accumulation of about 8,000 cubic yards of material. Size analysis of the accumulated silt in the borrow pit indicates it averages 80 percent finer than 0.062 millimeter in diameter. The material composing the bottom in the immediate vicinity of the borrow area, in June 1960, had a median diameter ranging from 0.29 to 0.36 millimeter. Also, the percentage of material finer than 0.062 millimeter in diameter, composing the bottom, ranged from 0.1 to 0.5 percent. Thus the sand fraction composing the bottom around the borrow pit has not been transported any significant distance in any direction over the period of record. Virtually none of the sand fraction of the material pumped on the beach has been transported far enough seaward to be deposited in the pit. The silt and finer materials deposited in the pit may have been partly from the sediments composing the bottom area surrounding the pit and partly from the fill material on the beach. The field data available for this study are not sufficient to provide definite clarification of the mechanics of sediment movement in the borrow pit area, but due to the presence of basically only silt deposits in the borrow pit to date, it is probable that the shoaling is a result of sorting of bottom sediments by waves and currents. The maximum orbital velocities of waves on frequent occasions are apparently of sufficient strength to move the silt and finer fraction into suspension, and thereafter wave-induced or tidal currents transport the suspended sediments. These suspended sediments settle out of suspension when transported over the pit area due to greater water depths and reduction in current strength; hence the shoal material in the pit contains a preponderance of silt and smaller sizes.

The borrow pit is filling at a relatively slow rate. Seaward progression of the toe of the beach fill is from 300 to 400 feet landward of the pit and presently available data will not allow a prediction of when sand movement into the pit will be appreciable. Therefore, the rate of filling of the pit over the 3-year period is not necessarily indicative of the future filling rate. The location of the borrow pit offshore from the beach was apparently satisfactory. Although borrow pits are not usually located as close as 1,000 feet offshore, the fact that loss of beach-size material into the pit is not evident indicates that borrow close to the beach is satisfactory under conditions obtaining in this area.

The data do not show the net effectiveness of the groins. They were apparently constructed to suitable dimensions, as no area within the system or downdrift thereof shows recession by reason of a reduced supply of littoral drift. Since none of the annual surveys showed the study area to have beach dimensions less than recommended project dimensions, it may be reasoned that the groins have tended to minimize short-term fluctuations in the beach widths, particularly during periods of storm conditions. Annual costs of the groins are equivalent to the placement costs of about 3,000 cubic yards of material on the beach each year which is slightly greater than 20 percent of the presently indicated annual nourishment requirements of 13,000 cubic yards. It seems reasonable to assume that nourishment requirements without groins would have exceeded 16,000 cubic yards.

The cost of the initial improvement, including the prorated overhead and engineering costs, was \$348,576. A breakdown of these costs is given below:

<u>Item</u>	<u>Quantity</u>	<u>Cost</u>
Sand Fill	442,960 c.y. (beach measurement)	\$290,696
Storm Drain Inclosures	-	1,800
Stone Groins	6,868 tons	<u>56,080</u>
		<u>\$348,576</u>

Based on the estimated nourishment requirement for sand fill, as indicated by losses to date, annual charges for a 50-year period may be estimated as follows:

Interest on investment	\$11,675
Amortization	2,790
Maintenance	
13,000 c.y. of sand at \$0.75	9,750
42 tons of stone at \$10.	<u>420</u>
	<u>\$24,635</u>

Considering the 6,470 feet of shoreline within the study area, shore stability will be obtained at a cost of about \$3.80 per lineal foot of shore per year. No periodic nourishment of the beach fill had been undertaken as of June 1960. A nourishment program must be initiated not later than 1965 and preferably earlier if beach widths comparable to those existing in 1960 are to be maintained and if the annual cost per lineal foot is expected to be kept to as low a figure as computed above. Allowance of excessive recession of the beach will not only increase the potential of damage to structures located immediately back of the beach but will decrease the efficiency of operation of the groin system, expose them to more severe wave attack, and thus increase maintenance costs for these structures.

Conclusions

The study presented herein has resulted in the following conclusions:

- a. The beach fill placed in February 1957 has provided a protective beach over a 3-year period the dimensions of which have been equal to or greater than project dimensions.
- b. The average annual loss of material from the project shore by littoral forces was about 13,000 cubic yards for the 3 years of record.
- c. The feeder beach for nourishing the remainder of the project shore should be located along the southerly part of that shore.
- d. The material used for the beach fill was of suitable size characteristics.
- e. The location of the borrow area was suitable for wave conditions which have existed in the area since placement of the fill and shoaling of the borrow area has been limited to silty material.
- f. The annual cost of providing the desired beach stability for the study area has been in the order of \$3.80 per lineal foot of shore.
- g. The groins have operated as anticipated and have probably reduced maintenance requirements to a degree justifying their construction.

Acknowledgements

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BEACH EROSION BOARD, C.E., U.S. ARMY, WASH., D.C.

BEHAVIOR OF BEACH FILL AND BORROW AREA AT PROSPECT BEACH, WEST HAVEN, CONNECTICUT, by W. H. Vesper, August 1961, 29 pp., 11 illus., 3 tables.

TECHNICAL MEMORANDUM NO. 127

UNCLASSIFIED

1. Artificial nourishment
2. Beach Fill
3. Connecticut - Artificial nourishment - Prospect Beach
4. Prospect Beach, Conn.
- I. Vesper, W. H.
- II. Title

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